



ACM-V



# SCIENTIFIC BULLETIN

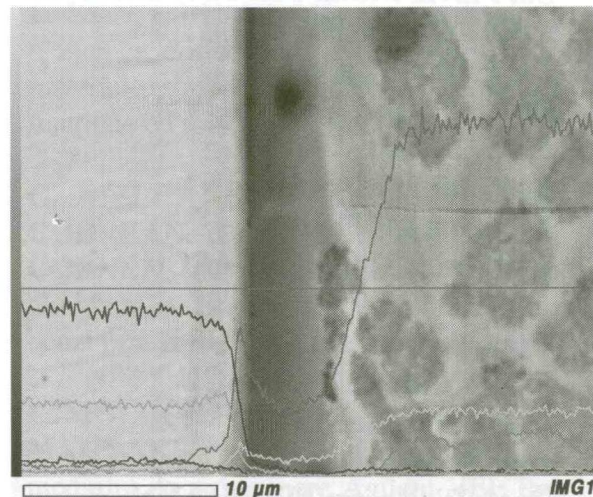
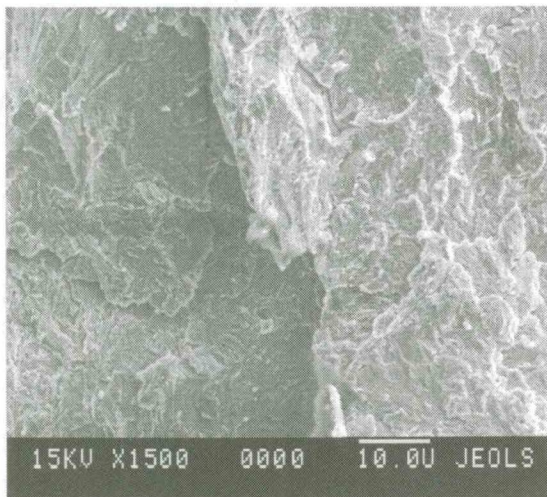
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## DEVELOPMENT AND INVESTIGATION OF A BALANCING SYSTEM USING FLUIDIC MUSCLES

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**Abstract.** The most significant disadvantage of pneumatic systems is nonlinearity. Due to the nonlinear behavior pneumatic artificial muscles (PAMs) are difficult to control, therefore a fast and robust control necessary to achieve the desired motion. Several control ways have been applied to control different humanoid or robot arms, manipulators, prosthetic and therapy devices driven by pneumatic artificial muscles. The early control methods were based on classical linear controllers and then some modern control strategies have been developed (e. g. adaptive, fuzzy, neural network, sliding-mode, others). This paper presents the investigation of a balancing system using Fluidic Muscle actuators and sliding-mode control.

**Keywords:** Pneumatic Artificial Muscle, Balancing System, Sliding-mode Control, LabVIEW

### 1. Introduction

Pneumatic actuators have been considered as a substitute of electric motors because of their high power/weight and power/volume ratio. Comparatively new type of pneumatic actuators the pneumatic artificial muscle, which possesses all the advantage of traditional pneumatic actuators. For this reason, they are common used in robotic systems as actuators of industrial robots or rehabilitation robots, etc. PAMs were introduced by Garasiev in the 1930's, but these muscles were limited to use because of limited material technology at that time. Later, in 1950's McKibben invented braided pneumatic actuator to help the movement of polio patient. In 1980's Bridgestone proposed a redesigned and more powerful version of McKibben muscle named Rubbertuator. Until

now different types of PAM have been developed and applied [1, 2].

Pneumatic muscle actuators consist of a rubber bladder enclosed within a helical braid that is clamped on both ends. When the bladder is pressurized the volume increases and the braid and clamps act to shorten the overall length of the actuator. During this movement the muscle converts pneumatic energy into mechanical form [3].

The layout of this paper is as follows. Section 2 (Materials and Methods) is devoted to demonstrate the experimental setup (hardware and software environment). Section 3 (Experimental Results) presents some experimental results and



finally, section 4 (Conclusions and Future Work) gives the investigations we plan.

Fluidic Muscles type DMSP-10-250N-RM-RM (with inner diameter of 10 mm and initial length of 250 mm) produced by Festo company were selected for this study.

## 2. Materials and Methods

Different experimental setups have been developed to investigate pneumatic systems [4, 5, 6, 7, 8, 9].

Our new balancing system is shown in Figure 1. The PAMs were installed vertically and can be controlled by a proportional valve type MPYE-5-M5-010-B made by Festo. The positioning was measured with a BDF-6360-3-05-2500-65 type (produced by Balluff) rotary incremental encoder with  $0.036^\circ$  resolution. A National Instruments data acquisition card (NI 6251/M) read the signals of incremental encoder into the PC. Between the DAQ card and encoder an I/O device type SCB 68 was attached with a special connecting cable.

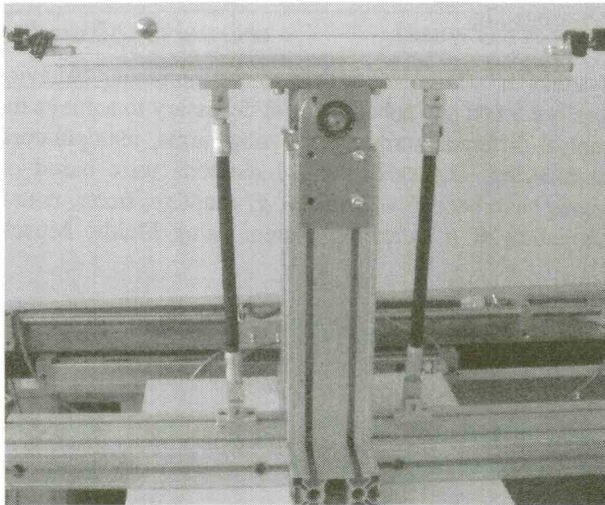


Figure 1 Balancing system

Because of the difficulties caused by the nonlinear properties of pneumatic systems a LabVIEW based sliding-mode control was designed. The design of a sliding-mode controller consists of three main steps. One is the design of the sliding surface, the second step is the design of the control which holds the system trajectory on the sliding surface, and the third and key step is the chattering-free implementation.

Good descriptions of our control system and experimental results of accurate positioning (0.01 mm) can be found in [10, 11].

In this study the purpose of positioning is to use the antagonistic muscles to balance the bearing in a desired position. With the use of sliding-mode control the positioning error can be minimized.

The Figure 2 shows data acquisition and positioning that can be achieved in LabVIEW environment. Aside from the current position the desired position and the control signal can also be set. The data can be saved into a text file.

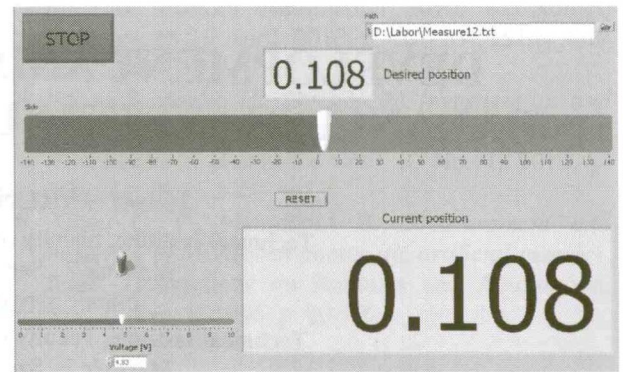


Figure 2 Front panel of LabVIEW program

## 3. Experimental Results

Positioning was done in room temperature on the pressure of 6 bar, the sampling time was 10 ms. When choosing the slope of the sliding surface the optimum between two concurrent properties must be found (speed, accuracy). The smaller the slope the faster the trajectory reaches the sliding surface, but it will take longer to set. The angle of the sliding surface was set to  $26.56^\circ$  ( $\tan \alpha = 0.5$ ). The time function of the position and control signal is shown in Figure 3 and Figure 4. To show the accuracy of positioning a short interval has been magnified (Figure 5 and Figure 6). If an error occurs, the system responds immediately. The position error of the LabVIEW-based sliding-mode control is within  $0.036^\circ$ . This means that the accuracy of the system is limited by the applied rotary incremental encoder.

The control program (control signal [V]) was based on Table 1.

Table 1 Control program

Fast Forward	Slow Forward	In Position	Slow Backward	Fast Backward
4	4.8	5	5.2	6

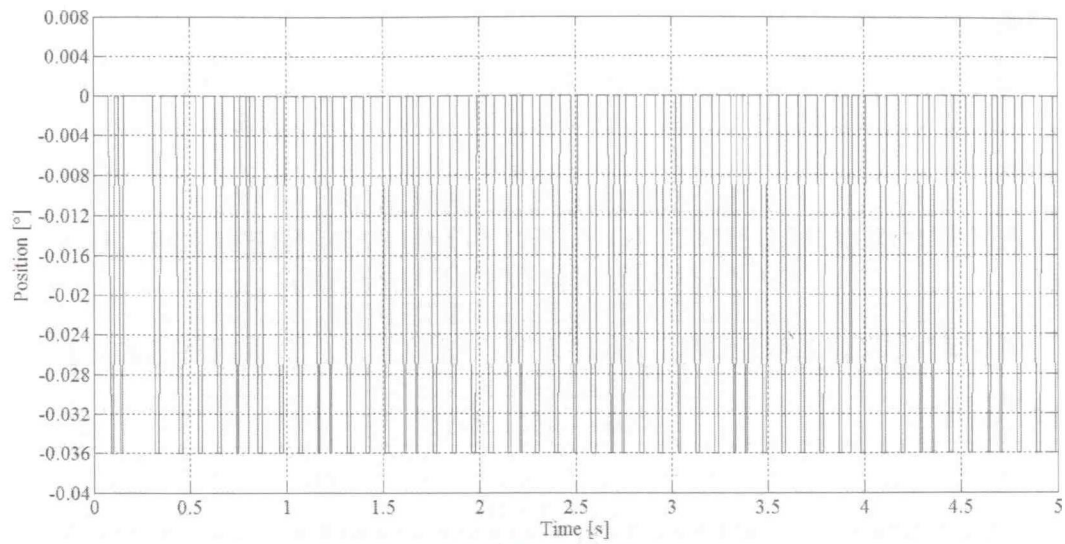


Figure 3 Position as a function of time

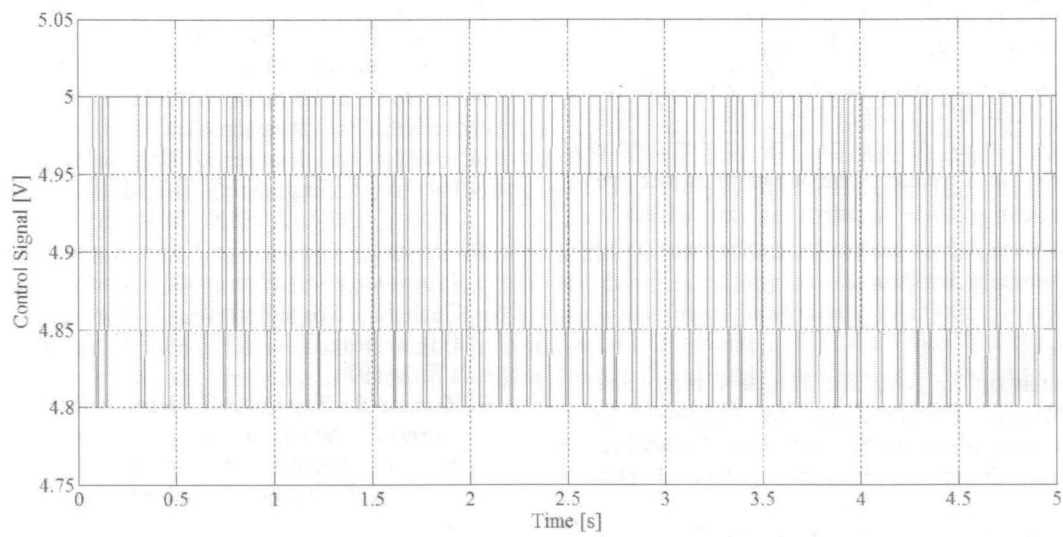


Figure 4 Control signal as a function of time

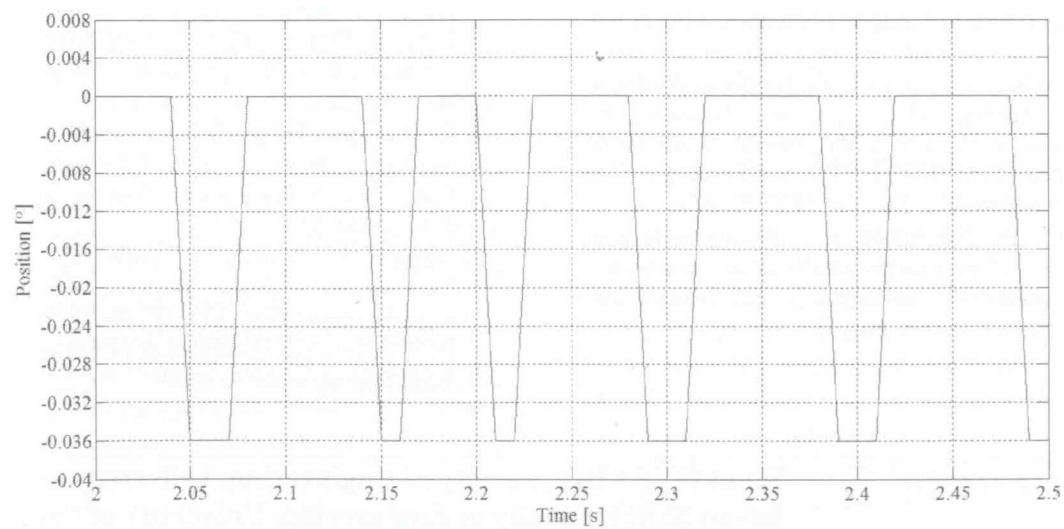


Figure 5 Position as a function of time (enlarged)



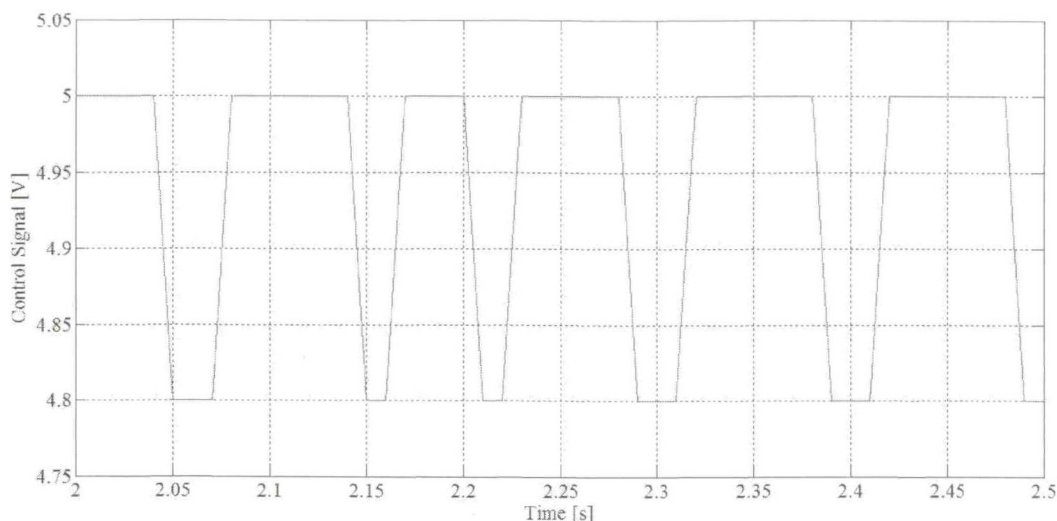


Figure 6 Control signal as a function of time (enlarged)

#### 4. Conclusions and Future Work

In this work a new balancing system using Fluidic Muscles was described. For precise positioning ( $0.036^\circ$ ) a LabVIEW based sliding-mode control was designed. The experimental results show an excellent control performance and that the sliding-mode control is an effective method to develop an accurate mechanism using pneumatic muscle actuators.

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